

POLIMOD Pipeline: tutorial: step-by-step tutorial

Dominique Boutet, Jean-François Jégo, Vincent Meyrueis

▶ To cite this version:

Dominique Boutet, Jean-François Jégo, Vincent Meyrueis. POLIMOD Pipeline: tutorial: step-bystep tutorial. [Technical Report] Université de Rouen, Université Paris 8, Moscow State Linguistic University. 2018. hal-01950615

HAL Id: hal-01950615 https://hal.science/hal-01950615v1

Submitted on 11 Dec 2018 $\,$

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers. L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

POLIMOD Pipeline: step-by-step tutorial

Motion Capture, Visualization & Data Analysis for gesture studies

Dominique Boutet, Université de Rouen, France, <u>dominique.boutet@univ-rouen.fr</u> Jean-François Jégo, Université Paris 8, France, <u>jean-francois.jego03@univ-paris8.fr</u> Vincent Meyrueis, Université Paris 8, France, <u>vincent.meyrueis@univ-paris8.fr</u>

Abstract

This open-access tutorial describes step-by-step how to use motion capture for gesture studies. We propose a pipeline to collect, visualize, annotate and analyze motion capture (mocap) data for gesture studies. A pipeline is "an implementation of a workflow specification. The term comes from computing, where it means a set of serial processes, with the output of one process being the input of the subsequent process. A production pipeline is not generally perfectly serial because real workflows usually have branches and iterative loops, but the idea is valid: A pipeline is the set of procedures that need to be taken in order to create and hand off deliverables" (Okun, 2010).

The pipeline designed here presents two main parts and three subparts. The first part of the pipeline describes the data collection process, including the setup and its prerequisites, the protocol to follow and how to export data regarding the analysis. The second part is focusing on data analysis, describing the main steps of Data processing, Data analysis itself following different gesture descriptors, and Data visualization in order to understand complex or multidimensional gesture features. We design the pipeline using blocks connected with arrows. Each block is presenting a specific step using hardware or software. Arrows represent the flow of data between each block and the 3-letter acronyms attached refer to the data file format.

Table of contents

Pipeline Overview	3
1. Data collection	4
1.1 Setup & Device	4
1.1.A Select the Device	4
1.1.B Conditions and Environment	4
1.2 Protocol	5
1.2.A Before the recording	6
1.2.B During the recording	6
1.3 Export Data	6
1.3.A Filetypes	7
1.3.B Filenames	7
2. Analysis	7
2.1 Data Process	8
2.1.A Extracting Data: Save the raw file into .bvh	8
2.1.B Explanation about the kinesiological attribution and the orientation of the XYZ axis	10
2.1.C Merging Data (video and mocap) BVH Data to Video (Blender)	12
2.1.D Mocap Video and Unity	17
2.2 Data Analysis	20
2.2.A Coding aspectuality (bounded and unbounded gesture) in Elan	20
2.2.B Pipeline to approach the Flow in Excel	22
2.2.C Pipeline to determine the way to find the kinematics in data computing using Unity3D a 28	nd Excel
2.3 Visualizing results and interpretation	28
2.3.A Visualizing aspectuality and statistics in Excel	29
2.3.B Kinesiology & Kinematics: Statistics and Curve Analysis in Excel	29
2.3.C Augmented Reality Player in Unity3D for gesture descriptors	31
Acknowledgment	32
References	32

Pipeline Overview

1. Data collection			2. Analysis		
1.1 Setup Device and characteristics	1.2 Protocol before & during Recording	1.3 Export Data and filenames	2.1 Data Process (Extraction & Merging)	2.2 Data Analysis Elan / Excel / Unity	2.3 Visualizing results and interpretation

1. Data Collection 1.2 PROTOCOL 1.3 EXPORT DATA 2.2 DATA ANALYSIS 1.1 SETUP 2.1 DATA PROCESS 2.3 VISUALIZING RESULTS VIDEO-BASED MOV DATA ANALYSIS in Elan (CSV) XLS MOV MOV RAW Video file with Audio & Kinematics tatistics) In Exce XLS XLS RAW Mocap file MOV Result Augmented Reality Player in Unity3D DATA ANALYSIS in Unity3D (CSV) FB) (BVH) REAL-TIME Motion Capture Video + Motion Capture → Data & calculus 🗕 🗕 🔶 Optional Elan _

table 1: pipeline overview

table 2: detailed pipeline

1. Data collection

The data collection process is the first part of the pipeline, we detail the **Setup & device** and the prerequisites. Then we propose a **Protocol** to follow with specific guidelines and finally we describe how to **Export data** depending on the analysis tools and outcomes.

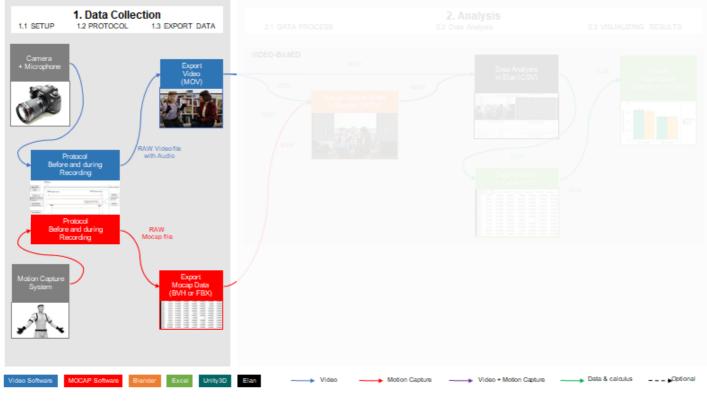


figure: data collection step

1.1 Setup & Device

The protocol involving motion capture is slightly different from a traditional data collection using a single video camera.

1.1.A Select the Device

Camera : 25 FPS, or 50 FPS (more accurate) or 60 FPS gives a better accuracy especially in slow motion. Since video and audio channels are now recorded with the same device, there is no special requirement for synchronizing data, be sure the sound is recording properly and the frame rate is correct.

Regarding Mocap, the selection of the device is important. Indeed, many motion-capture system exists (mechanical, optical, inertial...), with different use cases, accuracy and price. In our case, we opt for an inertial system (Perception Neuron) which appears to be more convenient in terms of accuracy (millimeters), frequency (from 60hz to 120hz), and this type of mocap suit solves occlusion problems compared with an optical system.

1.1.B Conditions and Environment

We, however, had to be very careful regarding the experiment conditions and environment. Actually, inertial

motion-capture system uses IMU (Inertial Measurement units) which are very sensitive to the ambient magnetism of the environment. We suggest to first learn more about the way IMU are working (Magnetism, Gyroscope, Accelerometer). If the magnetic environment is totally different from the one when the sensors were calibrated we recommend to a full calibration of the sensors. If some sensors present a latency despite a proper calibration, we suggest avoiding placing them on critical joints for the recording (such as root, hip, chest, head...) putting them on the body parts not needed for analysis (for instance in the legs of the feet). To sum up, here is the check list:

- Magnetism of the environment (general recommendations, how to measure it)
- Minimal knowledge about how the IMU work (Magnetism, Gyroscope, accelerometer)
- (Re)-Calibration of the sensors
- What we have to do with sensors which present a latency (putting them on the body parts we won't need for analysis, ex. legs and feet, avoiding critical joints such as root, hip, chest, head...)

1.2 Protocol

1.1 SETUP 1.2 PROTOCOL 1.3 EXPORT DATA			
Carrier • Microphone Weight of the series			
Video Software MOCAP Software Blender Excel Unity3D	Hiteo Mot	ion Capture Video + Motion Capture	Data & calculus

figure: synchronizing audio/video with mocap

The protocol involving motion capture is slightly different from a traditional data collection using a single video camera.

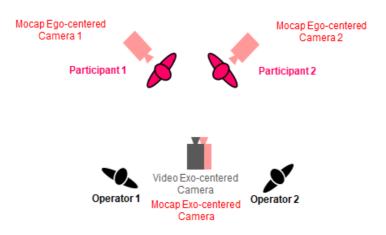


figure: data collection of two participants using video camera (in gray) and motion capture "virtual" cameras (in red)

1.2.A Before the recording

- The material (table, chairs, background)
- The clothes for the subjects and their personal environment (no black cloth, no black background, solid background...)
- General Counseling about the equipment of the suit (strap placement)
- The wearing of the device, i.e. exact placement of the sensors on the body, tightness of the straps (not too loose neither too tight).
- What you have to know about the subjects (sex, height)
- Calibration phase (How to make it, where to do it, locking of the positions)
- Naming (Protocol, height)

1.2.B During the recording

- Sync with the video (first claps at the beginning and a second at the end of the recordings)
- First Evaluation for the accuracy of the recordings

During the recording phase of the data collection, we recommend the participant to adopt a specific posture called T-Pose. This pose is required then to set up properly the virtual body (avatar) in a 3D engine. It is important to synchronize the mocap with the video and the audio recordings. To do so, we suggest the participant after the T-Pose to clap their hands once at the beginning of the recording and also one more time at the end of the recordings. In this way, operators can do a quick evaluation for the accuracy of the recordings and check if data is not missing or drifting.

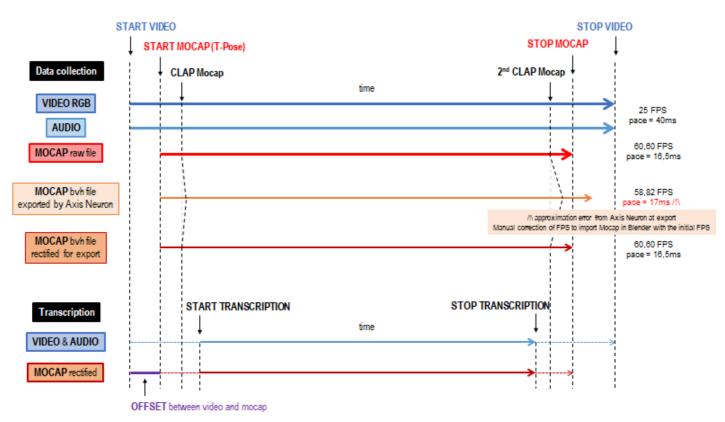


figure: synchronizing timelines with posture, claps and explanation of data asynchrony

1.3 Export Data

After the data collection, we need to synchronize properly the audio/video with the motion recorded. To do so, we have to be sure of the frame rate of each file. For instance, a video file has typically a frame rate of 25 FPS, 30 FPS or 50 FPS. Regarding the motion capture, the device we use (Perception Neuron) record movement at 60,6060 FPS (pace = 16,5 ms). However we note a simple export to BVH sets in the exported file

a pace at 17 ms which appears to be an approximation of 16,5 ms. This results in obtaining a longer motion capture file (in time) than the raw mocap file since the same number of frames is played at a slower pace. In this case, we have to correct the file export manually in order to generate for instance a video in the Blender 3D software. In this way, the total length is correct and can be synchronized properly with the audio and video files from the camera.

1.3.A Filetypes

Regarding the file types, video files and mocap can then be exported to different file formats. Please note there are sometimes some compatibility issues (for instance MacOS MOV file types are not always readable for Windows PC). In our case, we opt for the H264 open source codec in MOV video files.

1.3.B Filenames

About the filenames, different templates exist (DCNC, 2018) but some of them could be too exhaustive which makes more difficult to read. In our protocol, we choose uppercase initials, numbers and dash for separation. Thus, we write VR for Video Recording (VR1, VR2, if multiple cameras), SR for Sound Recording if the sound track is separated from the video, MC for Mocap Capture recording, and VM for Video Motion capture (VM1, VM2, if we render multiple points of view). We associate then to each participant's language initials of the group (for instance RU for Russian, FR for French participants) and a number. We also add to the end of the filename the heights of the subject as a suffix for specific software export where this information is needed. We obtain for instance MC-RUFR01-1m66 for the Motion Capture file of the participant 01 speaking Russian as a native language and French as a second language and whose height is 1.66 meters.

-	Video Recording	VR (VR1 VR2 if multiple cameras)
-	Sound Recording	SR
-	Mocap Capture recording	MC (also add a suffix the heights of the subject ex. MC-FRFR01-1m66)
-	Video Motion capture	VM (VM1 VM2 if multiple points of view)

2. Analysis

The analysis part is the second main part of the pipeline we design. This part is also divided in three steps. The first one in the **Data Process** which consists of extracting or merging data from the raw file of the data collection. Then we proceed to the **Data Analysis** itself. This step is dependent on the type of studies or output expected. In this study, we wish to both conduct statistical analysis but also understand movement and find new gesture descriptors in action, i.e. using real-time playback and visualization. The last step consists of **Visualizing Results** and its interpretation.

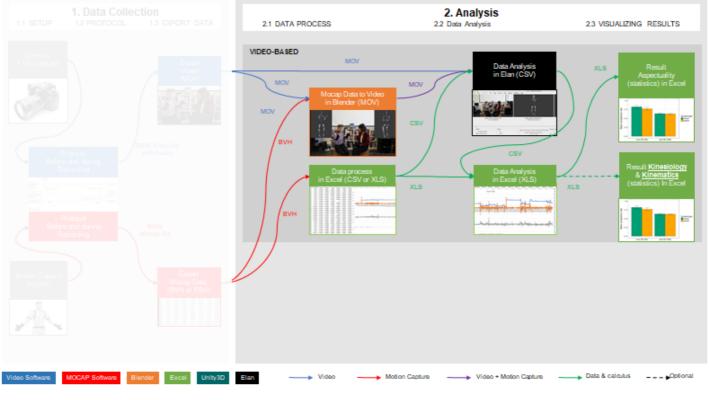


figure: part 2. Analysis

2.1 Data Process

The data process is dependent on the Data export and is necessary to prepare the Data analysis. The most standard and open mocap file format is BVH (Biovision Hierarchy). A mocap file is generally composed of a header and a table of data. The header of the mocap file defines the skeleton, the height or size of each bone and the pace to play the file. In the table, each column corresponds to specific coordinates of each joint of the body and each row is the value of the coordinate at each frame. When exported as an ASCII text file (such as a BVH) the mocap file could be open and manipulated or transformed in Excel. But we could also import the mocap file in Unity3D in a binary format (such as FBX file format) which includes extra feature to simplify the import and, thus, makes import more convenient in 3D software. In this study, we need to prepare data regarding our three main outputs: Generating an Excel file from the mocap, Generating a skeleton in video from the mocap and Generating a real-time skeleton (avatar) from the mocap.

2.1.A Extracting Data: Save the raw file into .bvh

- Open the raw file in Axis Neuron (File, Open)
- File > Export ; filetype: Biovision BVH
- Select rotation order Rotation: YXZ ; Tick the box "Displacement"

Data information in Excel sheet format

- Open the BVH with OpenOffice (it could be long). You will have this kind of text :

HIERARCHY
ROOT Hips
{
OFFSET 0.000 85.175 0.000
CHANNELS 6 Xposition Yposition Zposition Yrotation Xrotation Zrotation
JOINT RightUpLeg
{
OFFSET -10.500 -1.535 0.000
CHANNELS 6 Xposition Yposition Zposition Yrotation Xrotation Zrotation
JOINT RightLeg
{
OFFSET 0.000 -39.400 0.000
CHANNELS 6 Xposition Yposition Zposition Yrotation Xrotation Zrotation
JOINT RightFoot
{
OFFSET 0.000 -37.320 0.000
CHANNELS 6 Xposition Yposition Zposition Yrotation Xrotation Zrotation
End Site

Select the data (more or less at the 6th pages), beginning at the end of the hierarchy information and ending to the end of the file.

	■ 114_1_prise 1_1m60_AdeleDom.bvh - OpenOffice Writer	
🖹 • 볼 • 🔲 👒 🛃	🗟 🖴 🖎 🔆 👑 😹 🖌 🐁 🏗 • 🎸 🦈 - 🕲 · 🕲 🔠 • 🛷 🏙 🖉 🧰 🗑 🖷 🔍 🤣 📋 Recherche 👱 🦑 💮	
Texte préformat	🔽 Times New Roman 🔽 10 🔽 G / S 📰 🗄 🗄 🛱 🏭 🎼 🌾 🍜 🖉 - 💆 -	
L	<u>····1···∑····1</u> ···2· <u>·</u> ·3··· <u>1</u> 4··· <u>5</u> ···6 <u>·</u> ··7· <u>·</u> ·8·· <u>·</u> 9··· <u>1</u> 0···11 <u>·</u> ··12· <u>·</u> ·13·· <u>·</u> 14··· <u>1</u> 5···16 <u>·</u> ·· <u>17</u> ···18···	1 4
21 - 20 - 19 - 18 - 17 - 16 - 15 - 14 - 17	MOTION Frames: 33756 Frame Time: 0.017 1.698082 55.30830 - 35.940815 -112.197670 -5.106575 -0.045331 -10.526116 -1.511344 -0.006106 59.362240 45.945023 -59.595886 -0.011563 -39.406597 0.001029 74.480934 69.405319 90.074738 0.024051 -37.858948 0.218407 27.225185 -20.623207 -8.125589 10.513308 -1.570663 -0.007414 16.387947 -75.527878 15.081161 0.020869 -39.421387 -0.032417 -173.886581 75.251961 1 c5.55671 -0.211311 -3.681052 -0.008272 9.3841861 55.019119 42.694054 0.014994 13.814346 0.013877 19.328472 14.261142 4.806843 0.008024 9.384884 0.006998 4.827903 2.803464 0.640095 0.009317 9.772178 0.012952 7.804756 3.901816 1.222520 0.008272 9.384106 0.012052 2.464356 0.358570 -0.77531 0.032710 0.012508 22.41751 -0.08478 -2.600298 0.008274 9.384884 0.008254 8.293010 0.003186 31.703293 19.911781 -7.076328 -3.992594 6.685444 0.023970 -0.327586 -2.490430 -2.261763 -12.389478 -0.004620 0.037416 24.426260 -6.788324 46.575218 -20.988615 -0.013571 0.026285 53.008961 43.285828 1.755677 -23.004000 -0.013723 0.032820 14.366577 -0.13605 -4.400000 -0.000000 -4.918737 -0.086147 0.94208 31.500000 -0.000000 5.03598 -3.415484 0.00000 0.000000 -9.313164 -2.412126 0.000000 0.000000 -77.413422 -0.000000 0.3009474 0.479368 1.865368 0.00000 -0.000000 -4.918737 -0.086147 0.94208 0.300000 0.000000 5.3598 -3.316884 0.00000 0.000000 -0.000000 -4.918737 -0.086147 0.94208 0.300000 0.000000 5.3598 -3.316884 0.00000 0.000000 -0.000000 -0.000000 -4.918737 -0.086147 0.94208 0.300000 0.000000 5.3598 -3.31588 0.00000 0.000000 -0.000000 -0.000000 -4.918737 -0.086147 0.94208 0.300000 0.000000 5.3598 -3.31588 0.00000 0.000000 -0.000000 0.017410 -1.934842 0.000000 0.000000 0.000000 0.000000 -0.000000 0.000000 -0.000000 -4.918737 -0.086147 0.94208 0.300000 0.000000 0.000000 0.000000 -0.000000 0.000000 -0.000000 0.000000 -4.878442 -0.079200 0.25558 0.000000 0.000000 0.000000 -0.000000 0.000000 -0.000000 -4.47384 -3.172850 0.000000 0.000000 0.000000 -4.47384 -3.172850 0.000000 0.000000 0.000000 -4.47384 -3.172850 0.000000 0.000000 -4.47384 -3.172850 0.000000	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Page 6 / 632	Standard Français (France) INS STD	⊕ 108 %

Copy and paste this data in a new OpenOffice file (.TXT) and change the extension of this file into ".csv". -Open this .csv file into Open office. You should have this first window: _

	li li	mport de texte	- [ESSAI114.cs	sv]		
nporter						ОК
Jeu de caractères	Unicode (UTF-8	5)	;	0		OR
Langue	Par défaut - Fra					Annule
Lunguo		liçais (Flance)		~		
À partir de la ligne	1 🗘					Aide
ptions de séparateur						
Largeur fixe						
Séparé par						
✓ Tabulation	Virgule		Autres			
			/101/03			
Point-virgule	🗹 Espace)				
Fusionner les sép	arateurs	S	Séparateur de l	texte "	<u> </u>	
utres options						
Champ entre guillem	ets comme texte					
Détecter les nombres	s spéciaux					
hamps						
Type de colonne		\$				
Standard Standard	d Standard	Standard	Standard	Standard	Standa	
1 1.698082 55.308						
2 1.701995 55.308						
3 1.701185 55.308						
4 1.699726 55.307						
5 1.697215 55.313						
6 1.693329 55.313	702 -35.945698	3-112.14769	0-5.138092			
7 1.690516 55.310						

Do not forget to save as .xlsx (or .xls). Close it. You can re-open it from Excel. -

Open the File "Template Neuron BVH yxz" which contains the right naming for each column. This template is built for 6 dimensions per sensor.

• • • 🗈	⊡ ≌ 'Ŭ ₹			Template	e Neuron BVH x	yz to		Cherc	her dans la feuille	0
Accueil Insert	ion Mise en page	Formules Do	nnées Révision	Affichage					<u></u> - Partag	ger ^
	alibri (Corps) 🔹 12		= = %	Renvoyer à la ligne autor		Standard	• 🛃 • 🍃	· 🎻 🛶		<mark>A</mark> ₹₹∙
Coller 🧹 🤇	GI <u>S</u> V	🌺 • 📥 • 🚍	Ξ Ξ • Ξ •Ξ	↔ Fusionner et centrer *		≥ % 000 % .	Mise en forme Mettre conditionnelle forme de	sous Styles de tableau cellule	vlise en forme * 🥜 *	Trier et filtrer
2 ‡ × •	√ fx									
A .	в	с	D	E		F	G H	1	1	_
Timespan	Hip Tx	Hip Ty	Hip Tz	Hip Rx	Hip Ry	Hip Rz	RightUpRight Tx	RightUpLeg Ty	RightUpLeg Tz	

- Paste the content of the file .xlsx (or .xls) you just save in this template file.

•••	KO ▼ Ű ₹			🖾 114_1_pri	se 1_1m60_A	leleDom			Ch	ercher dans la feuil	le
Accueil Insertion	n Mise en page	Formules Don	nées Révision	Affichage							🖺 + Partag
Coller 🧹 G	bri (Corps) * 12 I <u>S</u> * · ·		= = >> •=	Eusionner et centrer *	matiquement	Standard	▼ 00, 00, 0, 00,	Mise en forme Mettre sous conditionnelle forme de tableau	Styles de	Insérer * Supprimer * Mise en forme *	
B2 ♣ × ✓	f _x 1.698082	c	D	5		e e	6	н			
1 Timespan	Hip Tx	Hip Ty	Hip Tz	Hip Rx	Hip Ry	r Hip F		RightUpRight Tx	RightUpLeg Tv	RightUpLe	,
	1.698082	55,308830	-35,940815	-112.197670	-5,106575		5331	-10.526116	-1.511344	-0.006106	
	1.701995	55.308254	-35.934883	-112.197670	-5.106575	-0.04		-10.526670	-1.510136	-0.004229	
	1.701185	55.308578	-35.935631	-112.173958	-5,130377	-0.03		-10.521810	-1.512282	-0.008489	
	1.699726	55.307114	-35,940464	-112.147690	-5.138092		0949	-10.519137	-1.510490	-0.010655	
	1.697215	55.313446	-35.942684	-112.147690	-5.138092		0949	-10.513385	-1.513524	-0.009936	
	1.693329	55.313702	-35.945698	-112.147690	-5.138092	-0.05	0949	-10.513634	-1.512144	-0.007779	j.
	1.690516	55.310928	-35.947712	-112.144012	-5.143877	-0.06	2524	-10.512329	-1.510080	-0.005587	<i>i</i>
	1.690107	55.310749	-35.946529	-112.142052	-5.147985	-0.06		-10.517659	-1.507729	-0.007176	ś
0	1.687746	55.310501	-35.941185	-112.165771	-5.140366	-0.06	6613	-10.510607	-1.507341	-0.000430	i
1	1.687832	55.308487	-35.940300	-112.155258	-5.149800	-0.05	9632	-10.506416	-1.508708	-0.002190	j.
2	1.691316	55.311989	-35.945030	-112.145050	-5.154369	-0.05	3745	-10.505565	-1.512822	-0.004272	t .
3	1.692407	55.311222	-35.948887	-112.156418	-5.157868	-0.05	1419	-10.506988	-1.516884	-0.002773	\$
1	1.697099	55.307152	-35.953789	-112.158203	-5.156195	-0.04	5354	-10.506426	-1.510463	-0.002490	j .
5	1.699877	55.304562	-35.954800	-112.131165	-5.162321	-0.0E	0090	-10.507124	-1.512619	-0.008258	\$
5	1.698645	55.304443	-35.956650	-112.142609	-5.165811	-0.05		-10.502463	-1.514350	-0.007314	
7	1.698141	55.301811	-35.960915	-112.171104	-5.162869	-0.03	5851	-10.497331	-1.514341	-0.003596	\$
8	1.695850	55.290867	-35.963364	-112.158806	-5.160222	-0.04	1230	-10.497325	-1.512792	-0.003650	j
9	1.697752	55.283142	-35.966740	-112.159698	-5.159380	-0.03		-10.493059	-1.517377	-0.004078	\$
	1.702909	55.279362	-35.970669	-112.172478	-5.154720		4406	-10.488814	-1.517391	-0.001721	
1	1.707819	55.278362	-35.975277	-112.158539	-5.151306	-0.04	6410	-10.492112	-1.516376	-0.003426	;
2	1.711380	55.282307	-35.977943	-112.148148	-5.144554	-0.04		-10.500560	-1.509264	-0.002729	i .
3	1.713972	55.282593	-35.980625	-112.149483	-5.136411	-0.04		-10.502091	-1.501013	-0.000999	
1	1.715290	55.278851	-35.977142	-112.158470	-5.123785	-0.05	9024	-10.504394	-1.503085	-0.001234	6
5	1.714266	55.278610	-35.970264	-112.168976	-5.114355	-0.0E		-10.502836	-1.507486	-0.001865	
6	1.706723	55.278118	-35.965244	-112.166306	-5.116868	-0.07	5106	-10.498654	-1.509923	-0.000863	() () () () () () () () () ()

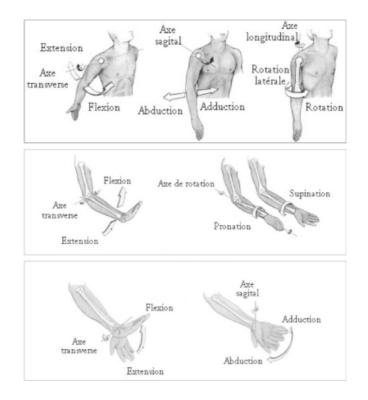
Now you have the data in the right name for each column. You only need to generate the timespan.
 The time of the first frame is 00, the second 17ms and so on. You can write the first 5 timespan : 0 - 17 - 34 - 51 - 68. Select this first five lines and double-click on the little Cross (right of the last Cell).

2.1.B Explanation about the kinesiological attribution and the orientation of the XYZ axis

The first step is the naming of the kinesiological movement.

In the figure just below the top bloc figures the Arm Movement (Flexion/Extension, Abduction/Adduction and Interior/Exterior Rotation). The middle bloc concerns the forearm (Flexion/Extension and Pronation/Supination). The bottom bloc figures the movements of the Hand (Flexion/Extension and the Abduction/Adduction).

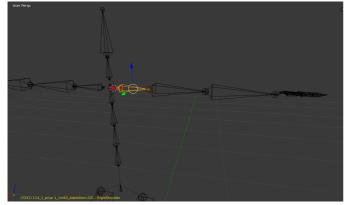
Each Movement is turning around a joint. For instance, the Flexion/Extension of the arm is due to a circular movement around this transverse Axis, as you can see (top bloc).

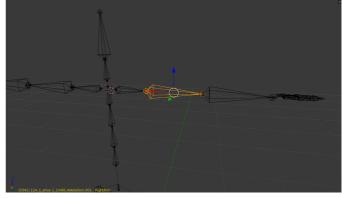


The axis is not always perpendicular to a joint. Some of them are along bones. For the rotation of the arm, the axis is along the humerus. Another movement has to the same feature: the pronation/supination. The axis is along the radius and the ulna.

- How can we label the right movement in a XYZ system of coordinates?
- In T-Pose, we can determine the orientation of the XYZ axis for each segment. These are the Orientation of the Shoulder, the Arm, the Forearm and the Hand.

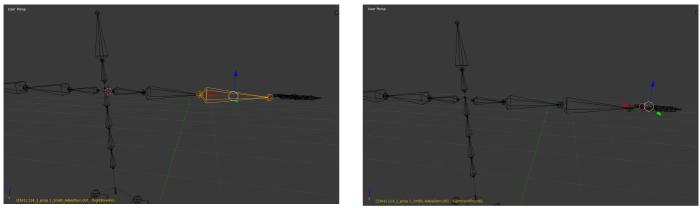
The RED ARROW represents the X Axis The GREEN ARROW represents the Y Axis The BLUE ARROW represents the Z Axis.





The right shoulder in Blender

The right arm in Blender



The right forearm in Blender

The right hand in Blender

This is a table which sums up the correspondences between the kinesiological naming and the XYZ coordinate system. For each Movement, the first pole is positive in the Axis, the second corresponds to negative values.

XYZ coordinate system	Right Shoulder	Right Arm	Right Forearm	Right Hand
X axis		Exterior/Int Rot.	Pro/Supi	
Y axis	Add/Abd	Add/Abd	Flex/Exten	Flex/Exten
Z axis		Flex/Exten		Abd/Add

For the Left upper limb, the values are in the other way around. It is Exterior/Int Rot. instead of Interior/Ext Rot. for the right upper limb.

For the arm sensor, we have the X axis along the arm, the Y axis is towards the back and the Z axis is towards the left

This means: the rotation axis X corresponds to the rotation of the arm, the rotation axis Y corresponds to the abduction/adduction and the rotation axis Z corresponds to the Flexion/Extension

For the forearm the X axis is along the forearm, Y is next to Ulna and Z pierces the forearm perpendicularly. This means: the rotation axis X corresponds to the prognostication, the rotation axis Y corresponds to the extension bending and the rotation axis Z corresponds to the abduction/adduction

2.1.C Merging Data (video and mocap) BVH Data to Video (Blender)

To generate a video with the mocap skeleton, we use the Blender software which can import natively BVH file format and allow to render sequences of images and, so, videos. Be sure the frame rate of the BVH file is correct. Indeed, in our workflow, we discover while using Blender that Axis neuron software creates an approximation error during export. This results in generating a video with an incorrect length. To solve this issue, we had to manually correct the BVH file as explained previously.

We also develop a real-time tool using Unity3D to visualize skeleton and gesture descriptors. Unity3D software is mainly developed and used for real-time data processing and visualization but it also allows to export videos, we propose then in the pipeline an optional MOV export from Unity3D 3D to Elan software for annotation (table 2)

We use this software:

- Axis 3.8.42.6503 calculation engine 3.2.2.7251
- Blender version 2.78c

1. Preparing the BVH for Blender

IMPORTANT: when exporting a BVH file from Axis Neuron, the default timeframe is 0.017. However it should be 0.0165. The first thing to do is to edit the BVH file using a text editor (or OpenOffice).

2. Create a New scene

File> Create a New scene

WARNING: first set the scene frame rate to 60 FPS (right panel: Properties > Dimensions > Framerate select 60)

File > Import BVH

💫 Blender (① - File Render Window Help = Default ↔ 🐼 🛃 - Set	▼ Import BVH	MC-FRFR01.bvh
Crf N To Gran. Crf O To Gran. Svift Crf O > Resert. Svift Crf O >	Forward: -Z Forward	<u>۴</u>
Recover Last Session Session Frequence Auto Save	Up: YUp 🛟	MC-FRFR01.bvh
Image: Save Ctrl S Image: Shift Ctrl S Shift Ctrl S	Target: Armature	MC-FRFR01_FrameTime0165.bvh
Save Copy Ctrl Alt S User Preferences Ctrl Alt U Save Scartup File Ctrl U		MC-FRFR02_1m66.bvh
Save Startup File Ctrl U	0.016	MC-FRFR03.bvh
参 Link Ctrl Alt O 教 Aggend Shift F1 Data Previews	Start Frame: 1 >	MC-FRFR04-1m66.bvh
Gelada (Default) (.dae) GEptot ▷ Alembic (.abc)	Scale FPS	MC-FRFR05.bvh
v De ■ External Data → 3D Studio (.3ds) FBX (.fbx)	Update Scene FPS	MC-FRFR06-1m58.bvh
U Quit Ctrl Q Motion Capture (.b/h) Stanford (.ply) Wavefront (.obj)		MC-FRFR07.bvh
<u>X30</u> Extrode 3D (x3d/wrl) Sg(.stri)	Update Scene Duration	MC-FRFR08-1m48.bvh
Scalable Vector Graphics (.svg)	Loop	MC-FRFR09.bvh
	Rotation: Euler (Native)	MC-FRFR10_1m66.bvh
🛛 💽 🗘 View Select Add Object 💽 Object Mode 🛊 💽 🛊 🚱 🗼 🖉		
-40 -20 0 20 40 60 80 1 Image: Start Image: Start<		

Select the file

On the left panel:

- Tick Scale FPS
- IMPORTANT Don't tick Update Scene FPS
- Tick Update Scene Duration
- Change the scale from 1 to 0.016 (means the height of the subject is 1.60m)

Optional: Scaling the head for better visibility

On the hierarchy menu (right panel): select Pose One the viewport: Select the head (right click) On the transform panel set the scale values of X and Z axis to 3.0

9 Mem:770.24M MC-FRFR05		
	▼ Transform	E= View Search All Scenes
	Location: * X: 0.00000) * Y: 0.00000) * Z: 0.00000) Rotation: * X: -8.968°) * Y: 13.465°) * Z: 4.578°) * Z: 4.578°) * Z: 3.000) * Y: 1.000) * Z: 3.000)	 Scene PrenderLayers World World Animation Animation<!--</td-->
	Scene Object Scene Object Image: Scene New New Layer View	Scene ▼ Render mm
	(* Lens: 35.000 >)	Render Animation (1) Audio

Optional: Customizing animation

- On the hierarchy, select the hip
- on the **Graph Editor**, **uncheck the speaker icon** in order not to play the Hips XYZ locations (i.e. positions) animation

 ▼ № 114_1_prise 1_1m60_ ▼ № 114_1_prise 1_1m60_ ○ X Location (Hips) ○ Y Location (Hips) ○ Z Location (Hips) ○ X Euler Rotation (Hips) 	AdeleDom		
Y Euler Rotation (Hips) Z Euler Rotation (Hips) Z		5000 10000150002000	002500030000
View Select Ma	arker Channel	Key 🥰 F-Curve 🛊	N 🔝 🚱 🔎 (

Rendering animation

Check the resolution

- Preset HDTV 1080p can be reduced to a lower resolution: 720p
- Frame rate to 60fps (smoother animation) can be reduced to 30 editing the framestep to 2
- Antialiasing to 5 or 8 (better quality), can be unchecked creating lower edge quality with pixels

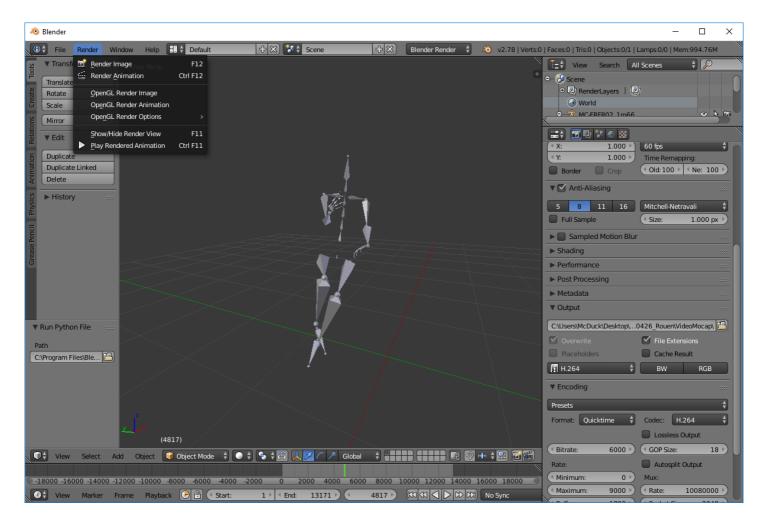
	大 🖌 🏷 🔀	v		
🔊 🞖 Scene				ſ
▼ Render				
🐻 Render	🖆 Anin	nation	c())	Audio
Display:	Image Editor			÷ 🕞
▼ Dimensions				::::
HDTV 1080p				++-
Resolution:		Frame Range	:	
	1920 px 🖹	Start Frame	2:	1)
≪ Y:	1080 px 🕨	End Frame:		33757 ▶
	100%	🔄 Frame Step		1 >
Aspect Ratio:		Frame Rate:		
	1.000)	60 fps		÷
	1.000 🕨	Time Remap	ping:	
Border Cro	qq	Old:	100 🕨 🖣 Nev	w: 100 🖻
🔻 🗹 Anti-Aliasing				
5 8 11	16	Mitchell-Netr	avali	÷
Full Sample		Size:		1.000 px 🕨

output

- format QuickTime
- h.264

Output						
C:\Users\McDuck\D	esktop\POLIMOD_17	-18\POLIMOD_1704	27_Paris\MocapVideo\	VM-FRFR	12_30FPS_HalfHD.mov	B
🕑 Overwrite			Sile Extensions			
Placeholders			Cache Result			
H.264		\$	BW		RGB	
▼ Encoding						
Presets				_		÷
Format:	Quicktime	\$	Codec:	H.264		¢
			Lossless Output			
(Bitrate:		6000 🖻	GOP Size:		1	18 🕨
Rate:			Autosplit Output	:		
Minimum:		0 🖻	Mux:			
(Maximum:		9000 🖻	(Rate:		1008000	00 🖻
Buffer:		1792 🖻	Packet Size:	_	204	18 🕨
Audio Codec:		None	_			¢
(Bitrate:		192 🖻	Volume:		1.00	00

Render the video



 First, check the virtual body fits the image size top left menu: Render > OpenGL Render image If not, adjust the view of the viewport

2. if it's correct, launch the video rendering top left menu: **Render > OpenGL Render Animation**

IMPORTANT: in windows, do not reduce or interact with the blender window during the rendering, it makes Blender crash

Creating a video with MOCAP

Open Blender

Change Default Layout to Video Editing - On the menu on top of the timeline, go to: Add > Movie > Select the RGB Video from the camera

then Add the 2 Mocap Video rendered previously: Add > Movie > Select the RGB Video from the camera

8 Blender [C:\Users\User\Desktop\POLIMOD_17-18\POLIMOD_1704			- 0 ×
C File Render Window Hep . C Video Editing C 2 Scene	🕂 🔀 🛛 🖬 🕹 🕹 w2.78 [Wests8 Faces6 Tris 12 Objects 1/8 Lamps 0.1 Mer	m22.5849 (c.de	
Total Total <th< td=""><td></td><td></td><td></td></th<>			
X V Some			
▼ Render			1 T
Render gij	Animation 🛛 🖓 Audio		
Displays Image Editor			
▼ Dimensions			I at 1
Render Presets			
Resolution: (-X): < 10	Frame Range 1920 px - V Start Frame		4
 K K 	1080 px > 1 < End Frame:	1031	
	100% Frame Stept		
Anext Male Anext Male 2 x 2 x 2 konter	1:00 / 25 tps		<u> </u>
1.16	1.000 » Time Remapping:		
Border Drop	(* Old: 100 + * New:		
🔻 💟 Anti-Alasing			
5 11 10	6 Hitchel Netravali		
	(Sze		
Sampled Motion Blur			
► Shading			
Post Processing			
k g long kaloniku k konnacz k konnacz k konnacz k konnacz k konnacz Comm ∑ Domm ∑ Domm © Istał			
₩ Output			
(Amp.			
Coerwrite	 He bitmions Coche Resit 		
B Raceholders			
III H264	0 EW ROB		
▼ Encoding			
Prosts			
Format: Quidtime	Codec: M264		
	6000 -) (+ GDP Sze		
. Barr	Atoxic Odnat		
			▼ Edit Szip
			Name VM-RER13_251PS.L.
			Type: Novie d
			Stand Over Drop \$
			(Opacity: 1000 ()
			(* Stat Frame: 533 *)
•	Fareform.001 13926		(*Length: 13928.>)
			Final Length: 00.09:37:03 Playhead: 3926
			Frame Offset 0.0
	VMFRFR14_25FPS_lowHD.mov//VMFRFR14_25FPS_HafHD.mov/13926		Frame Still 0:0
			Original Dimension: 960x540
	Taratien 13028		¥ Strip Input
			Patr: (VMERFR13 25FPS)
			MPEG Presex: 25
	VHFMR13_25PPS_lowHD.mox /VHFRR13_25PPS_HaltHD.mov 13928		(Streen Index: 0)
			image Offset
			image Crop
	VRFRFR13-14.MOV_IL_Wdeckecording/VRFRFR13-14.MOV 14359		Tim Duration (hand):
			(Start: 0 > (End: 0 >
	WRFRFR13-14.001: JL:WiderRecordingDFFFRFR13-14 MOV [14358		Trim Duration (soft):
			(Sat 0)
6 02 20 02 10 02 50 01 50 01 40 01 10 01 20 01 10 01 20 00 50 00 40 00 10 00 20 00 10 00			09.30.09.40.0
Vew Select Marker Add Frame Strip 🖉 🖬 🗮 🗟 🖉 🖉 Refessio	Sequencer 🖉 Use Backdrop 🤘 👾		
19000 -18000 -17000 -15000 -15000 -14000 -18000 -12000 -11000 -10000	0 4000 4000 -7000 4000 5000 4000 -3000 -7000 -1000 0	1000 2000 5001 4000 5000 5000 5000 5000 5000 1000 1	000 27000 28000 29000 30000 0
Vew Marker Frame Playback 🕑 🗄 (+ Start: 1 + + End: 14358 +) (+	4551 D H H 🖉 🕨 H Nafanc 🕴 🗃 🔹 🛊 😥 😥		

2.1.D Mocap Video and Unity

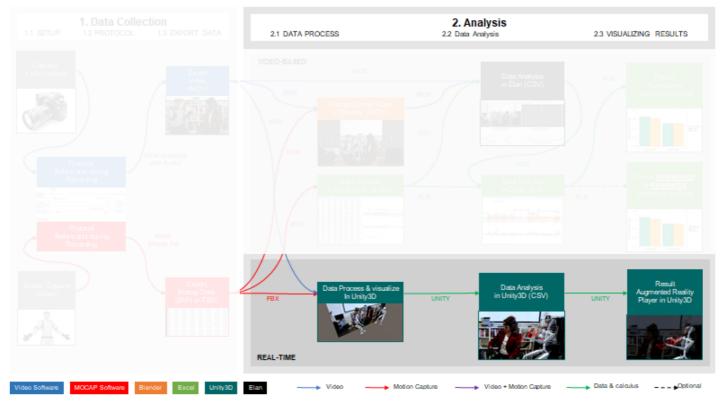


figure: Import Mocap and Elan in Unity

We propose a tool to import and merge in Unity3D Audio/video with Elan annotation and Mocap

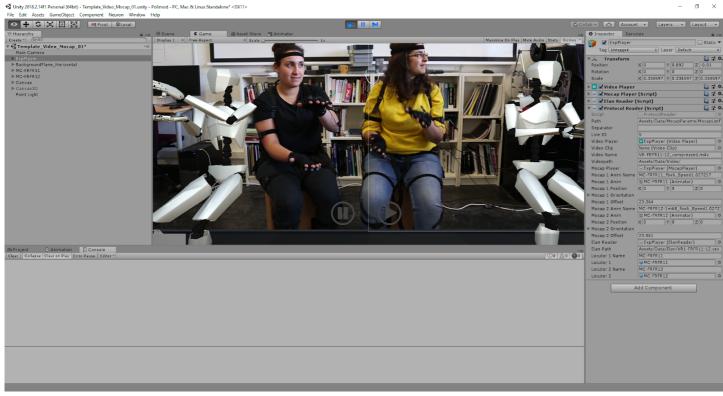


figure: Unity3D Interface

Script description:

🔻 📾 🗹 Protocol Read		\$,			
Script	ProtocolReader				
Path	Assets/Data/MocapParams/MocapLis	аtF			
Separator					
Line ID	5				
Video Player	ExpPlayer (Video Player)	0			
Video Clip	None (Video Clip)	0			
Video Name	VR-FRFR11-12_compressed.m4v				
Videopath	Assets/Data/Video/				
Mocap Player	ExpPlayer (MocapPlayer)	0			
Mocap 1 Anim Name	MC-FRFR11_fbx6_Speed1.027217				
Mocap 1 Anim	BMC-FRFR11 (Animator)	0			
Mocap 1 Position	X 0 Y 0 Z 0				
▶ Mocap 1 Orientation					
Mocap 1 Offset	23.364				
Mocap 2 Anim Name	MC-FRFR12-1m68_fbx6_Speed1.027	2:			
Mocap 2 Anim	MC-FRFR12 (Animator)	0			
Mocap 2 Position	X 0 Y 0 Z 0				
Mocap 2 Orientation					
Mocap 2 Offset	23.961				
Elan Reader	ExpPlayer (ElanReader)	0			
Elan Path	Assets/Data/Elan/VR1-FRFR11-12.csv				
Locutor 1 Name	MC-FRFR11				
Locutor 1	GMC-FRFR11	0			
Locutor 2 Name	MC-FRFR12				
Locutor 2	WC-FRFR12	0			

🔻 📾 🗹 Mocap Play	er (Script)	🔯 🕸 🔅
Script	MocapPlayer	0
Progress	0	0
Current Time	00:38:376	
Elan Time	38375.64	
Video Mocap Off S	et 0	
Video Normalized	Tir—0————	0.10450
Video Current Tim	e 00:38:375	
Video Duration	367.2	
Mocap Obj 1	WC-FRFR11	0
Mocap 1 Normalize		0.03836
Mocap 1 Current T	in 00:13:429	
Mocap 1 Duration	350.016	
Mocap 1 Time Scal	e 1	
Mocap 1 Offset	23.364	
Mocap Obj 2	WC-FRFR12	0
Mocap 2 Normalize	:d -O-	0.03673
Mocap 2 Current T	in 00:12:832	
Mocap 2 Duration	349.356	
Mocap 2 Time Scal	e 1	
Mocap 2 Offset	23.961	
Mocap Frame Rate		
Mocap Read Speed	1.027217	

🗖 🖬 Elan Reader (Script) 🔯 🗐 🗐
Script	ElanReader
Path	Assets/Data/Elan/VR1-FRFR11-12.cs
Separator	
Current Frame	367200
Frame Time	0
Load Gesture List Cou	40
Locutor 1 Name	LOC left Boundary-ARB-26Apr18
Locutor 1	MC-FRFR11
Locutor 1 Gesture List	31
Locutor 2 Name	DAC Loc Left
Locutor 2	MC-FRFR12
Locutor 2 Gesture List	9
Best Quality Name	dac
Best Quality Color	
Normal Quality Name	padac
Normal Quality Color	
Worst Quality Name	granpadac
Worst Quality Color	
Quality Colors	

Protocol reader:

This script connects all the elements (video, Motion Capture and Elan coding) for a given experimentation it also configures all the other scripts

The user just has to choose the number of experiments and click on play button

Mocap Player: (Managed by Protocol reader)

This script synchronizes the video of the experimentation and the different mocap recording at the same time base

It also gives the global control of the progress of the experimentation and allows to choose different key points for a contextualized gesture analysis

Elan Reader: (Managed by Protocol reader)

This script reads the exported coding file from Elan and transcodes the information to a locutor script specific to each speaker

It also transcodes the consensus information (DAC, PADAC, GRANPADAC) in an indexed value on a color gradient.

🔻 🖬 🗹 Gesture Reco	order (Script) 🔲 🖬	¢.
Script	GestureRecorder	0
Locutor	MC-FRFR11 (Locutor)	0
Mocap Play	ExpPlayer (MocapPlayer)	0
Left Hand Obj	GRobot_RightHand	0
Right Hand Obj	@Robot_LeftHand	0
Ref	@Robot_Spine3	0
Gesture_ID_Tag	GestureID	
Gesture_Type_Tag	GestureType	
Left Hand_Tag	LeftHand	
Right Hand_Tag	RightHand	
Speed_Tag	Speed	
Acc_Tag	Acc	
Jerk_Tag	Jerk	
Pos_Tag	Pos	
Quat_Tag	Orientation	
Time_Tag	Time	
Record		
Path	Assets/Data/Export/	
Gesture File Name	Gesture.csv	
Spectrum File Name	Spectrum.csv	
Separator		
Frame Count	89	
Spectrum Resolution	50	
🔻 🖬 🗹 Locutor (Scri	pt) 🔟 큐	\$,
Script	Locutor	0
Name	LOC left Boundary-ARB-26Apr18	
Current Frame	-2147483648	
Gesture Nb	-1	
Gesture Elan ID	-1	
Time	-35791:-23:-648	
Gesture Quality	0	
Gesture Type		
Quality Colors		
Quality Color		0

Gesture recorder: (Managed by Protocol reader)

This script retrieves the gestural information (Velocity, Acceleration, Jerk) for both hands of a speaker and writes them both to a specific and a global file in order to be able to do the statistical analysis

Locutor: (Managed by Elan reader)

This script triggers gesture on global time and gives information specific to the identification of each gesture coded with Elan

Image: Solution View (Script) Image: Solution View Record Image: Solution View Record Image: Solution View Prame Count 28440 Begin Time 10.7377 D Time 0.03710938 MD Time 0.04853516 Motion Obj Image: Solution View Pos Active Image: Solution View Pos Active Image: Solution View Pos Active Image: Solution View Gizmo Speed Scale Image: Solution View Speed_Col Image: Solution View Current Speed Xio Yio Zio Current Acc Xio Yio Zio Current Acc Mag Image: Solution View Jark Active Image: Solution View Gizmo Jerk Scale Image: Solution View Jerk_Col Image: Solution View Gizmo Jerk Scale Image: Solution View Jerk_Col Image: Solution View Gizmo Quat Scale Image: Solution View Gizmo Quat Scale Image: Solution View Gizmo Quat Scale Image: Solution View
Record Image: Count 28440 Begin Time 10.7377 D D Time 0.03710398 MD MD Time 0.04853516 Motion Ref Motion Ref Image: Robot_LeftHand 0 Motion Ref Image: Robot_LeftHand 0 Pos_Col Image: Robot_LeftHand 0 Current Pos X = 0.05160! Y = 0.33255! Z = 0.232918' Speed Active Image: Robot_LeftHand 0 Gizmo Speed Scale Image: Robot_LeftHand 0 Speed_Col Image: Robot_LeftHand 0 Current Speed Scale Image: Robot_LeftHand 0 Gizmo Speed Scale Image: Robot_LeftHand 0 Current Speed Mag 0 Image: Robot_LeftHand 0 Current Acc X = 0 Y = 0 Z = 0 Current Acc X = 0 Y = 0 Z = 0 Current Acc X = 0 Y = 0 Z = 0 Gizmo Jerk Scale Image: Robot_LeftHand Image: Robot_LeftHand Image: Robot_LeftHand Jerk_Col Y = 0 Z = 0 Image: Robot_LeftHand Image: Robot_LeftHand
Frame Count 28440 Begin Time 10.7377 D Time 0.03710938 MD Time 0.04853516 Motion Obj Robot_LeftHand 0 Motion Ref Robot_LeftHand 0 Pos_Col Image: Col Image: Col Current Pos X = 0.05160! Y = 0.33255! Z = 0.232918' Speed Active Image: Col Image: Col Gizmo Speed Scale Image: Col Image: Col Gizmo Speed Scale Image: Col Image: Col Gizmo Aces Scale Image: Col Image: Col Gizmo Jerk Scale Image: Col Image: Col Image: Col Image: Col Image: Col Gizmo Jerk Scale Image: Col Image: Col Image: Col Image: Col I
Begin Time 10.7377 D Time 0.03710936 MD Time 0.04853516 Motion Obj Robot_CelHand 0 Metion Ref Robot_Spine3 0 Pos_Col X 0.051605 Y 0.332555 Z 0.232918 Speed Active Image: Spine3 0 Image: Spine3 0 Gizmo Speed Scale Image: Spine3 1mage: Spine3 0 0 Current Speed Scale Image: Spine3 1mage: Spine3 0 0 0 Current Speed Scale Image: Spine3 Image: Spine3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
D Time 0.03710938 MD Time 0.0463516 Mation Obj @Robot_LeftHand 0 Motion Ref @Robot_Spine3 0 Pos Active Image: Coll Current Pos X = 0.051605 Y = 0.332555 Z = 0.232918 Speed Active Image: Current Speed Scale Image: Current Speed Active Gizmo Speed Scale Image: Current Speed Mage Image: Current Speed Active Gizmo Acc Scale Image: Current Acc X Image: Current Acc Acc, Col Image: Col Image: Col Gizmo Jerk Scale Image: Col Image: Col Jark Active Image: Col Image: Col Current Jerk Mag Image: Col Image: Col Current Jerk Mag Image: Current Acc Image: Col Current Jerk Mag Image: Col Image: Col Current Jerk Mag Image: Col Image: Col Current Jerk Mag Image: Col Image: Col Gizmo Quat Scale Image: Col Image: Col
MD Time 0.04853516 Mation Obj @Robot_LeftHand 0 Mation Ref @Robot_LeftHand 0 Pos_Active @ 0 Pos_Col @ 0 Current Pos X -0.05160! Y -0.33255! Z 0.232918' 0 Speed_Active
Metion Obj @ Robot_LeftHand 0 Metion Ref @ Robot_Spine3 0 Pos_Col @ 0 Current Pos X = 0.05160! Y = 0.33255! Z = 0.232918' 0 Speed Active Image: Col Image: Col Image: Col Gizmo Speed Scale Image: Col Image: Col Image: Col Image: Col Current Speed Mag Image: Col
Matian Ref Rabat_Spine3 0 Pos_Col Image: Col Image: Col Image: Col Speed Active Image: Col Image: Col Image: Col Speed Active Image: Col Image: Col Image: Col Current Speed Scale Image: Col Image: Col Image: Col Current Speed Mag Image: Col Image: Col Image: Col Current Speed Mag Image: Col Image: Col Image: Col Current Acc X Image: Col Image: Col Image: Col Current Acc X Image: Col Image: Col Image: Col Current Acc X Image: Col Image: Col Image: Col Current Jerk Acale Image: Col Image: Col Image: Col Current Jerk Mag Image: Col Image: Col Image: Col Current Jerk Mag Image: Col Image: Col Image: Col Current Jerk Mag Image: Col Image: Col Image: Col Current Jerk Mag Image: Col Image: Col Image: Col Current Jerk Mag Image: Col Image: Col Image: Col Image: Col
Pos Active Pos_Col Current Pos Current Speed Active Gizmo Speed Scale Current Speed Mag Acc Active Gizmo Acc Scale Current Acc
Pos_Col // Current Pos X -0.05160! Y -0.33255! Z 0.232918' Speed Active 1 Gizmo Speed Scale 1 Current Speed X 0 Acc Active 1 Gizmo Acc Scale 1 Acc_Col 1 Current Acc Mag 0 Jark Active 1 Gizmo Jerk Scale 1 Jark Active 1 Gizmo Jerk Scale 1 Orientation Active 1 Gizmo Jerk Scale 1 Jerk_Col 1 Gizmo Jerk Scale 1 Gizmo Jerk Scale 1 Gizmo Jerk Scale 1 Gizmo Jerk Scale 1 Gizmo Quat Scale 1
Current Pos X = 0.05160! Y = 0.33255! Z = 0.232918' Speed Active I Gizmo Speed Scale I Speed_Col I Current Speed Mag I Acc Active I Gizmo Acc Scale I Acc Active I Gizmo Acc Scale I Acc Active I Gizmo Acc Scale I Acc Active I Gizmo Jerk Scale I Jerk_Col I Current Jerk Mag I Orientation Active I Gizmo Quat Scale I
Speed Active Gizmo Speed Scale Speed_Col Current Speed Gizmo Acc Scale Gizmo Acc Scale Gizmo Acc Scale Gizmo Jerk Scale Jerk_Col Current Jerk X 0 Y 0 Z 0 Current Jerk X 0 X 0 X 0 X 0 X 0 X 0 X 0 X 0 X 0 X
Gizmo Speed Scale
Speed_Col X 0 Y 0 Z 0 Current Speed X 0 Y 0 Z 0 Current Speed Mag 0 Acc Active Gizmo Acc Scale 1 Acc_Col X 0 Y 0 Z 0 Current Acc X 0 Y 0 Z 0 Gizmo Jerk Scale 1 Jerk_Col 1 Current Jerk X 0 Y 0 Z 0 Current Jerk Mag 0 0 1 Orientation Active 1 1 Gizmo Quat Scale 1 1
Current Speed X 0 Y 0 Z 0 Current Speed Mag 0 0 0 Acc Active 0 1 0 Gizmo Acc Scale 1 1 0 Current Acc X 0 Y 0 Z 0 Current Acc X 0 Y 0 Z 0 Current Acc Mag 0 0 0 Jerk Active 0 0 0 0 Current Jerk Scale 0 Y 0 Z 0 0 Orientation Active 0 0 0 0 0 Gizmo Jerk Scale 0 Y 0 Z 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Current Speed Mag 0 Acc Active 1 Gizmo Acc Scale 1 Acc_Col 2 Current Acc X0 Y0 Z0 Current Acc Mag 0 3 3 Jerk Active 1 3 3 Gizmo Jerk Scale 1 3 3 Jerk_Col 7 0 2 0 Current Jerk X0 Y0 2 0 Orientation Active 1 3 3 3
Current Speed Mag 0 Acc Active 1 Gizmo Acc Scale 1 Acc_Col 2 Current Acc X0 Y0 Z0 Current Acc Mag 0 3 3 Jerk Active 1 3 3 Gizmo Jerk Scale 1 3 3 Jerk_Col 7 0 2 0 Current Jerk X0 Y0 2 0 Orientation Active 1 3 3 3
Gizmo Acc Scale
Acc_Col X0 Y0 Z0 Current Acc Mg 0 Z0 Jerk Active G G G Gizmo Jerk Scale 0 Y0 Z0 Jerk_Col Current Jerk X0 Y0 Z0 Current Jerk X0 Y0 Z0 Current Jerk Gizmo Jord Scale 0 0 1 1
Current Acc X 0 Y 0 Z 0 Current Acc Mag 0 0 0 Jerk Active 0 0 0 Gizmo Jerk Scale 0 1 0 Jerk_Col V 0 Z 0 Current Jerk X 0 Y 0 Z 0 Orientation Active 0 0 0 Gizmo Quat Scale 0 1 1
Current Acc Mag 0 Jerk Active Gizmo Jerk Scale Urrent Jerk X0 Y0 Z0 Current Jerk Mag 0 Orientation Active Gizmo Quat Scale
Jerk Active Gizmo Jerk Scale Jerk_Col Current Jerk X0 Y0 Z0 Orientation Active Gizmo Quat Scale
Gizmo Jerk Scale
Jerk_Cel Current Jerk X 0 Y 0 Z 0 Current Jerk Mag 0 Orientation Active Gizmo Quat Scale 1
Current Jerk X 0 Y 0 Z 0 Current Jerk Mag 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Current Jerk Mag 0 Orientation Active Gizmo Quat Scale1
Orientation Active Gizmo Quat Scale 1
Gizmo Quat Scale 1
Quat_Col 🏸
▶ Current Quat
Current Quat Axis X 1 Y 0 Z 0
Current Quat Angle 0
Trail
Trail Lines Width 0.1
Trail Length 120
Vector
Vect Lines Width0.1
Lines Materials None (Material)
Moving Average Sam 15

Motion view: (Managed by Gesture Recorder)

This script calculates and filters the different information for the kinematic (Velocity, Acceleration, Jerk) analysis of the gesture

It also allows to add colored VFX in order to visualize the information in real time on the avatar hands

2.2 Data Analysis

In this project, we conduct three types of data analysis: A. coding bounded and unbounded gesture in Elan, B. Determining the way to find the flow in data computing and C. Determining the way to find the kinematics in data computing. Depending on each type of analysis, we had to generate specific mocap file exports.

2.2.A Coding aspectuality (bounded and unbounded gesture) in Elan

This part is following a previous study investigating gesture aspectuality. Bounded and unbounded gestures have been coded using video. Using our pipeline which adds mocap, we have created a new corpus to analyze

gesture aspectuality across two languages : Russian participants speaking Russian as a first language, Russian participants speaking French as a second language, and French Participant speaking French as a first language (namely RURU, RUFR, FRFR). For this study, we design in the pipeline a workflow to generate videos from the mocap files using the open source software Blender. As we detailed in the previous part (2.1 Data process) Blender is a 3D rendering software that allows to generate sequence of images thus to generate video. Blender also integrates a video editing tool which allows to create picture in picture videos with the original video and audio from the camera and the mocap files rendered. We can then import this video in Elan and annotate gesture with mocap files superimposed in the video.

File Edit Annotation	Tier Type Search View Options Wind		2.eaf Subtitles Lexicon Comments Recogn	nizers Metadata Controls
n		Volume:		
		0 VM-FRFR11-12.mov	50 , , , , , , , , , , , , , , , , , , ,	100 · · · · · · · · · · · · · · · · · · ·
		Rate:	· · · · · · · · · · · · · · · · · · ·	
	00.91.50.927 5 4 5 4 5 5 5 5 5 5 5 5 5 5	_	de 📃 Loep Mode 📲	
	00:01:49.000 00:01:50.000 00	01:51.000 00:01:52.000 00:01:53.0	00 00:01:54.000 00:01:55.000	00:01:56.000 00:01:57.000
LOC left Full Trans	j(e) me suis + tout auto englouti dans			c'était l'année demière
LOC Left	suis	englouti	ai néussi	était
LOC left Tense For	pcA.	pcPART	pcAUX pcPART	impf
Loc right Time Mea			past pre-	
LOC left Hand Gest	Y		Y	Y
LOC left Boundary	bd-bounded		bd-bounded	ub-unbounded
[10]				

figure: coding bounded and unbounded gesture in Elan with video and mocap rendered picture in picture in the video

Synchronization in ELAN

ELAN allows to synchronize up to 4 media files (video or audio). So we can synchronize each video file with the video of the two MOCAP recordings. It allows to check visually sequences that we analyze.

Prerequisites

You have to keep in mind that the velocity of the recordings are different between the video (25 frames per second) and the Mocap with Neuron (60 frames per second). To be sure of the synchronization in ELAN, we need to be sure of the time in AXIS NEURON.

Build an excel sheet (proposed name: "Alignement Video-Mocap_Name Project_Month-Year"). The goal is to put together all of the sync information of the start (video, Mocap 1 and 2 and eventually the Audio), and of the claps. Some claps are not visible because the media is not started or because we cannot hear or see it.

• • •		□ 10 · 0 =			Align	nement Vidé	о Мосар			Chercher dans la	feuille 🙂
Accueil	Inse	rtion Mise en page	Formules	Données Révision	Affichage						🚔 + Partager \land
Coller	X [⊕ • [≪ [Calibri (Corps)	• A• A•	= = = », · = = = = •= •=	→ Renvoyer à la ligne autor → Fusionner et centrer *	matiquement	Standard	▼ (0,0,00) (0,0) (0,0)	Mise en forme Mettre sous conditionnelle forme de tableau Cellule	Insérer ×	∑ · A · Z · · Ø · Trier et filtrer
К2	\$ ×	✓ fx 257									
A	В	с	LE	F	н		1		J	к	
1 Type	N°	Clap Vidéo (frame vidéo en ms)	C Estimated start of the	e record Mocap / vidéo (frame video in ms)	Clap mocap / video (frame video in ms)	Estimation Clap mo	cap / video (conversion in fran	ne Mocap)	Estimated Clap mocap / video (conversion in frame Mocap)	Frame offset between Mocap's start :	and Mocap's Clap (in Frame)
E FR	114	0	8743 - 8898		12557			219,54	228,84		257
FR	113	0	8743 - 8898		12477			214,74	224,04		238
FR	112	15040	23320 - 23857		26960			186,18	218,4		197
FR	111	15040	23320 - 23857		27080			193,38	225,6		244
FR	110	14200	20368 - 22246		25800			213,24	325,92		348
FR	109	14200	20368 - 22246		25720			208,44	321,12		348 220
FR	108				38619			448,38	463,8		464
FR	107				38459			438,78	454,2		477
0 FR	106				20360			804,24	1020,9		833
1 FR	105				20120			789,84	1006,5		1065
2 FR	104				46800			937,62	954,78		678
3 FR	103				44960			827,22	844,38		139
4 FR	102				35120			1841,4	1969,8		1874
.5 FR	101	25400	2290 - 4430		31320			1613,4	1741,8		1782
6 RU-FR											
7											

Column F: Estimated start of the record Mocap / video (frame video in ms)

Values find in ELAN transformed in ms. This is an estimation regarding to the noise made by the starting beep of each Mocap recording system (we do not know which beep corresponds to which Mocap recording). We do not know the triggering moment during the noise. We put the two values of the beginning of the beep.

Column H: Clap mocap / video (frame video in ms)

These values are extracted from the video put in ELAN, as well. If the clap of a locutor is crushed during several frames, then we take into account the first frame in which the hand is stabilized.

Column I: Estimation Clap mocap / video (conversion in frame Mocap)

Formula : =(H\$2-highest value of F\$2)/(1000/60) — "(1000/60)" to calculate the exact duration for each frame in a 60f/s system.

Column J: Estimated Clap mocap / video (conversion in frame Mocap)

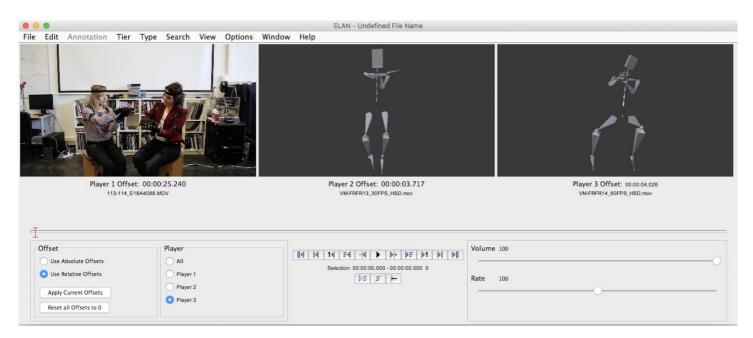
Formula : =(H\$2-lowest value of F\$2)/(1000/60). These two columns have no accuracy. They are useful to approximate the value of the last column.

Column K: Frame offset between Mocap's start and Mocap's Clap (in Frame) In Axis neuron, load the file.raw and search the exact moment of the Mocap clap for each locutor. The value is given in frame.

Now we have checked information about the different sync. We are able to synchronize the files in ELAN.

ELAN sync

Charge the video and the video of the Mocap in ELAN (New > Add media files). Once these video are loaded, go to the "Media Synchronization Mode" (in the tab Options). FIRST of all select the button "Use Relative Offsets".



For each video (Player 1, 2 and 3) select the same moment (the clap of the latest locutor). Sync the video Mocap. Then click on "All" and re-select the "Annotation Mode". Register the file as such with your naming protocol. Close and check if everything is OK. Be careful, Elan crops the video up to the shortest one.

2.2.B Pipeline to approach the Flow in Excel

A second analysis we chose to explore is the flow of movement. The flow is a transfer of a movement from one dof to another which determines the expansion of a shape on the upper limb. Regarding the Kinesiological criteria, we have:

- (quasi-)Co-linearity between Mvts ;
- (quasi-)Co-temporality between these Mvts :
 - with a temporal lag;

- without any temporal lag.

Unfortunately, at this moment, we are not able to measure the flow according to the three methods exposed above. We are able to approach the flow through three methods on one base. Our approach of the flow is calculated at every frame. The flow of each gesture is determined by the sum of every frame (simple arithmetic) according to:

1/ sliding windows ;

2/ mixing ratio between the degrees of freedom (dof);

3/ estimating the thresholds on the flow.

All the process is done with Excel. This software is not the most convenient to analyze data, but it presents some advantage. i/ its accessibility, ii/ a treatment more transparent for researchers who do not know how to code with C language or Python, iii/ The data coming from the Mocap, and from ELAN are compatible with Excel. The numbers of steps are numerous and are detailed in the next paragraph.

1/ Determine the exact offset between the video and the Mocap data.

Our advice for that is to upload Audacity software in order to "import" the .mov file ant to extract the audio ("export audio" in Audacity with a .wav format) to display it in ELAN into a wave like form (In ELAN: Edit > Linked Files > Choose the .wav file and "Add" it and "Apply" it). Then, you place the cursor in ELAN just before the "beep" of the Mocap recording for each locator and you have the offset in ms (see the offset on the screenshot below: 9182ms).

• • •		 RURU01-05_V01 reco 		ARB-nev-27avr18.ead				
Fichier Edition Annotation Acts	ur Type Rechercher	Affichage Options	Fenêtre Alde					
2 9.	• Los rig	Grille Texte Sou Ne ARB 26Apr18	a-titres Lexicon	Audio Recognizer	Video Recogniaer	Metadata		
	1	unded unded unded unded unded				00:06:06:436 00:06:12:212 00:06:17:087 00:06:20:074 00:07:08:972	00.08.08.064 00.06.13.838 00.06.18.256 00.06.21.118 00.07.09.395	000001428 000001726 000001789 000001.044 000000.423 000001.448
RHHHHHH		+ + 1 1	Minda de admition	O Made in South 1	,			
*			-					
-								
VR,RcR01-05,589a.wav	00.00.08.800	00.00.08.800	000.00.00	00 00 00 200	00.00.09.400	00.0	008.800	00.00.00
		a di Agradi se tra constante a consta	nanders and tender but in the	•		a state	***	*****
							***	****
· · · · · · · · · · · · · · · · · · ·	00.00.08.600	00.00-08.800	000.00-09.000	00 00 00 200	00.00.09.400	00.0	008.800	00:00:09
Loc right Tense Forms (Russian)				00.00.08.187				
Loc right ANB 26Apr18								
DAC Los right								
							_	

The value of this offset or the nearest value in the excel file giving the timecode is selected until the end of this column. These values will be pasted in the master file where we will add the data issued from ELAN and the mocap, as you will see in the step 6/a/ and following.

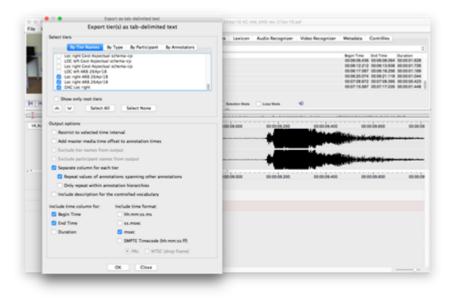
2/ Open the file .bvh coming from the Mocap and exported in XYZ order of rotation with TextWrangler or openedit. Copy Paste the data in a new file and leave the header with the chainings (as you can see below)

	Last Savel 10/11/2018 10:19 44 Tile Path # / /visures/VERA/TM HD/PC/Echanges Wescau mai 2018/PO/MOD_French Paris/MeterCapture/RevenParis/MC-PB/HDL_VP2.2wh
	< > > MC-F#R605,XYZ.MA 1 (2)
1017	CHEMNELS 6 Aposition Monition Zoosition Krotation Protation
10.00	302NT LeftmandFLrky3
10.00	
1000	OFFSET 1.583 0.000 0.000
10.011	OWANDLS & Xposition Yposition Xrutation Yrutation Zrotation
10.00	End 5116
10.00	0///// 1.564 8.868 8.868
234	
200	
100	
100	
100	
343	
341	
143	
242	
344	
245	
248	
347	
248) NOTEN
242	Ref 10k
-	France: 15405
-	Frames Links
-	5. 000000 54. 437751 8. 000000 -4. 570070 25. 710706 2. 004754 -10. 500000 -1.537754 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.00000000
and a	8. 000000 84.437243 8.000000 -4.570870 21.708706 2.004754 -18.500000 -1.537244 8.000000 8.000000 8.000000 8.000000 8.000000 -35.
2010	8.000000 54.437243 8.000000 -4.578870 25.758706 2.004754 -18.500000 -1.537254 8.000000 8.000000 8.000000 8.000000 8.000000 -35.
and a	8.000000 54.437243 8.000000 -4.578870 25.758706 2.004754 -18.500000 -1.537254 8.000000 8.000000 8.000000 8.000000 8.000000 -35.
1012	8.000000 84.437263 8.000000 -4.474822 25.687505 1.843058 -18.500000 -1.537264 8.000000 8.000000 8.000000 8.000000 8.000000 -25.
1010	8.000000 84.437263 8.000000 -4.477178 25.003064 1.845791 -18.500000 -1.537264 8.000000 8.000000 8.000000 8.000000 8.000000 -35.
1010	8.000000 84.437253 8.000000 -4.477178 25.003064 1.845791 -18.500000 -1.537264 8.000000 8.000000 8.000000 8.000000 8.000000 -35.
100	8.000000 84.437253 8.000000 -4.477178 25.603054 1.845791 -18.500000 -1.537254 8.000000 8.000000 8.000000 8.000000 -25.
1001	8.000000 04.437243 8.000000 -4.401455 23.000370 1.012212 -18.500000 -1.537254 8.000000 8.000000 8.000000 8.000000 -35.
1002	8.000000 84.437253 8.000000 -4.450745 23.655950 1.840002 -10.500000 -1.537264 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.00000000
1000	8. OPPOPER D4. 43/253 B. REPORTE 44. 472863 23. 005530 1.854366 -28. SECOND -3.537244 B. REPORTE B. REPORTE B. REPORTE B. REPORTE B. REPORTE -3.172144 B. REPORTE
-	5. DECEM B. 43771 8. DECEM -4. 4711 2. 5072 1. 35512 - 18. MARK - 1. 51724 8. DECEM F. BORNE S. BORNE
=	8.000000 84.437241 8.000000 4.473478 21.00114 1.003115 -18.500000 -1.517244 8.000000 8.000000 8.000000 8.00000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000
-	6.000000 84.437361 8.000000 4.462851 21.704304 1.852878 -10.500000 -1.517254 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000 8.000000
-	8. 000000 84. 437313 8. 000000 -4. 487834 21. 782471 1. 888218 -18. 500000 -1. 517244 8. 000000 8. 000000 8. 000000 8. 000000 8. 000000 -31.
1000	8.000000 84.437263 8.000000 =4.434745 25.705171 1.050506 =18.500000 =1.537264 8.000000 8.000000 8.000000 8.000000 8.000000 -25.
170	8.000000 84.437253 8.000000 =4.543154 25.718517 1.000372 =18.500000 =1.537254 8.000000 8.000000 8.000000 8.000000 8.000000 -35.1
10.71	8.000000 84.437213 8.000000 -4.520401 25.701738 1.910108 -18.500000 -1.517254 8.000000 8.000000 8.000000 8.000000 -25.

3/ Change the extension of the file from .txt to .csv and open it with OpenOffice. Choose the space as delimiters and save the file in an .xls format in order to open it with excel.

0.0	Import de te	exte - [Essai%201.csv]					
mporter				ОК			
Jeu de caractères	le caractères Unicode (UTF-8)						
Langua			Annuler				
Langue	Par défaut - Français (Fra						
À partir de la ligne	1 0			Aide			
Options de séparateur							
Largeur fixe							
 Séparé par 							
Z Tabulation	Virgule	Autres					
Point-virgule	Espace						
Fusionner les s	éparateurs	Séparateur de texte	•				
Autres options							
Champ entre guille	mets comme texte						
Détecter les nomb	res spéciaux						
Champs							
Type de colonne							
Type de colonne	0						
Standard Stand		Standard Standard	Standard				
	7263 0.000000 -4.578870						
	7263 0.000000 -4.578870 7263 0.000000 -4.578870						
	7263 0.000000 -4.578870						
	7263 0.000000 -4.578870						
	7263 0.000000 -4.477178						
		**************************************	*********				
	7263 0.000000 -4.477178	25.693064 1.845791	-10.500000				

4/ Export the transcription you need from ELAN (File > Export as > Tab delimited Text...). In the pop-up window, select the Tiers you want to export, dispatch them in separate column repeat values of annotation and select the Begin Time, the End time in ms (as you can see below). At this step, e have transformed in Excel format data issues from ELAN, data coming from the Mocap and the Synchronization data.



5/ From that point, we are going to put all the data presented in the last step into an excel template (.xltx) whom we detail in the next steps.

1	Accueil Insertion	Mise en page	Formules Données	Révision A	ffichage		<u></u>	+ Partager	^
_	_ (° •)	ri (Corps) + 12 I <u>S</u> + · · ·	A A A A	%		conditionnelle * rme de tableau * /le *	Cellules	Q, · Édition	
E4	\$ × ~	f_X							
	A	8	c	D	E	F	G	н	1
	Temps de départ - msec	temps de fin - msec	LOC left Boundary-ARB-26Apr18	Dac Loc Left	Tense				
2	83995		ub-unbounded	DAC	IMPERF				
1	136267	136911	bd-bounded	DAC	IMPERF				
						-			
0									
1									
2			1						
۹	ELAN Data RI	URU_LXX Mocapl	RURU_LXX_ELANSynchron	Fusion Rota BVH	et ELAN	Results RURUXX	+		

6/ The template is divided in 4 tabs.

a/ Tab one "ELAN Data RURU_LXXX" has four columns active and related to the other tabs. Beliw the labels, it is two lines pre-filled on which you can paste the data coming from your ELAN file (see step 1). This data will be reused in the tab 3 "Fusion Rota BVH et ELAN" (Merge Rotation BVH data and data coming from ELAN).

b/ Tab two "MocapRURU_LXX_ELANSynchron". The two other kind of data is pasted in this tab: the synchronization and the Mocap data. On the column "A", the timespan is pasted according to the offset determined in step 1/ (be cautious, the values taken from the first excel file contain a formula, you can copy them but paste them with the menu "Paste Special", choose "value"). In the second column Paste the Mocap value copy from the file created in the steps 2 and 3 (it could be long according to the duration of your recording). All of the data is pasted from the line 2. The first line contains the labels.

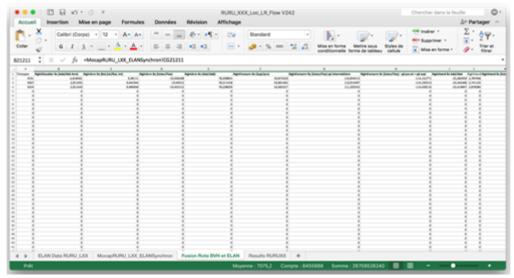
	Accueil	Insertion	Mise er	n page	Formules	Donnée	s Révi	sion Af	fichage			≟+ Parta	iger ^
	bler 💞	*	i (Corps) I <u>S</u> *	• 12 •	A* A*	 Alignement	% Numériq			conditionnel rme de table le *		. 4	on
D6	\$	$\times \checkmark$	f_X										
	A	8	с	D	E	F	G	н	1	J.	к	L	м
	Timespan	Hip Tx	Hip Ty	Hip Tz	Hip Ry	Hip Rx	Hip Rz	RightUpRight	RightUpLeg	RightUpLeg	RightUpLeg	RightUpLeg F	RightUpLe
2	9191	-20,329462	65,207481	4,823023	-19,541176	-7,186787	-7,688653	-11,591895	-1,67312	0,005378	-61,958721	18,700314	38,7887
3	9207	-20,330229	65,206879	4,831367	-19,544531	-7,204376	-7,693844	-11,589841	-1,674019	0,008917	-61,964096	18,712574	38,8078
4 5	9224	-20,32579	65,207909	4,835154	-19,544151	-7,192832	-7,689985	-11,585986	-1,674725	0,002737	-61,953983	18,702728	38,78
6													
7													
8													
9													
0													
1													
4	▶ EL	AN Data RU	RU LXX	MocapRU	RU LXX EL	ANSynchro	Fusion	Rota BVH	t ELAN	Results RUI	RUXX +		
	Prêt		no_bot	mocupitor	TO_EFFICEE	, and grade and	Tuston	Those Diffic	Ħ	11030113 1101			

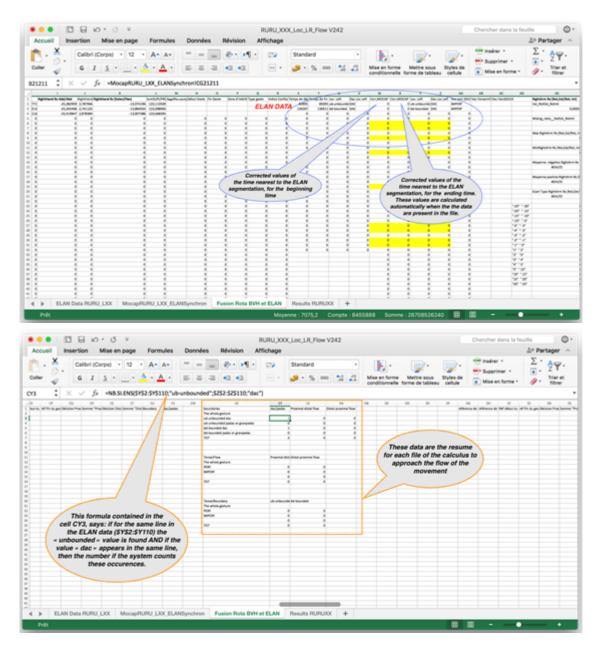
c/ The tab 3 named "Fusion Rota BVH et ELAN" is the core of the computation. Several functions are made automatically in this file:

i/ the alignment between the ELAN data and the Mocap Data, extracting just the data during the Gestures segmented in ELAN (first figure below)

ii/ the selection of the data we need for the analysis: only the rotation values (the values of translation are left out, the values of the right upper limb are interesting there and then copy from the Tab 2 (second figure below).

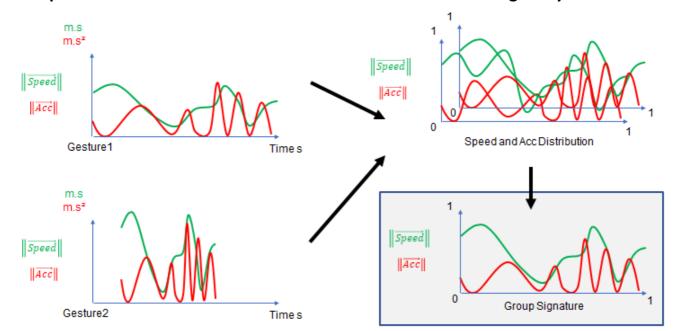
iii/ Anisgorithm involving the columns AE to EK are required to approach the flow ws th in three ways. iv/ All the calculation made in this tab are resumed in the sector CK 1 to DA26 (for whole gestures); DR1 to DU26 (for the first half part of the gestures with and without a mixing ratio), EL1 to EP26 (for the last half of the gestures with and without a mixing ratio) and GH1 to GK26 (for the whole gestures with a mixing ratio AND with a ponderation according to the standard deviation of each degree of freedom) (third figure below).





d/The tab 4 is composed of the resume for all the gestures of the file. In other words, the four sectors viewed in 6/c/iv/ are grouped in this tab (see the figure below)

and becaution there are not a firmer	the Provider Philippe	100-10-10	Li Butu
ell Insertion Mise en page Form	rules Données Révision	Affichage	∆+ Parta
V		The formula in the cell	SC9 takes the major - X - A
Calibri (Corps) • 12 • A.	A* = =		L'AQ.
A		value of the cell CY3	in the tab 3 w Supprimer - T
Contraction of the second second		= Fusion Rota BVH	
G I S	<u>.</u>	* Pusion Hota BYH	
· · · · · · · · · · · · · · · · · · ·			tallula 🔹 Mise en forme * 🦪 * filtrar
🗘 🛛 🗸 🧹 fix 🖃 Tusion Rota BVH et	ELANICIS		
	8 1 1 1 8 8 8 W		
More an Arithma an More an More an More an More and More	og ante Add that Maring ante Roma Pan Tand		Note any Note any Note and Note any Note any Note any Note any Note any Note that Note had
			toor has Floor has Floor has Floor has Floor has Floor has Floor has Rathout & too Rathout & too has
			Line Flag Flag for Flag Flag Flag Flag for Flag Flag Flag Flag Flag Flag Flag Flag
Incident decision Process de Dans process how	Annal Para Property do Data analysis has	Your Deep of advantation of the second	Includes Society President Data and the President Data and the President Society of Data and
The state where	Territor I I	Termina I I	Tenter I I I I I I I I I I I I I I I I I I I
distantial and a distant	10.00 0 0	1007 0 0	Automa 2 8 8 10 100 8
stationalization of the temperature of te	MANY I I	34597 8 8	distants I I I I I INTER I
Scheeleller 1 6 6			Newsell I I I I I I I I I I I I I I I I I I
Wheelefade E E E	310 E E	311 E E	Manada di di di di Mari di
14 E E			34 3 4 4
Incident decision Rectard do Data proving here	Interflate Proceed in Data proceed free		These results resume the analysis made for the
NUMBER OF THE T	Partnered I I		mark and to the bit \$. When the set of the
shahaabila 1 8 8	100 8 8		gestures in the tab 3 without any mixing ratio (see
distantial I I I	34507 1 1		line 2; 1,1,1,) but with a standard deviation
Monthle I E E			inte 2: 7,7,7,, out with a standard deviation
Manadal and S S S S		These results resume the	ponderation
		and the second deaths	pontenation
		analysis made for the	
Includes Access do Data proceed for	Interflare Property do Deal proceed free	gestures in the tab 3	
NAMES I I I	Teacher I I		
shahaabila 1 8 8	100 8 8	without any mixing ratio	
distantial I I I	34507 1 1		
Schooldar I 8 8		(see line 2: 1,1,1)	
Manadatan 6 6 6	M 1 8 8	Same must we shall seed	
			Mong and Add And Mong and them Pas Real
	and the second second second second second	a second as the distance in the second s	
Many and Rolling and Many and Many and Many and Many and Man	in site Add the Many are Aren for first		Kant han Khan han Khan han Khan han Khan han Khan han Khan han Kakilantik han hatilantik dan fin
1 M M I V V		These results resume the	THEN FAM FORM THEN THEN THEN THEN THEN
Involution declaring Proceed do Data proceed from			Australia Statute Proceed to Data second Tax
The state assister		analysis made for the	The state against
all colourabilities			all advantiated for
at advantationals of president		gestures in the tab 3 WITH	the extension of a second
Net Researched data			for investigation of the second
he housed patter or property		a mixing ratio (see line 37:	Tel Resulted parties of groupodes
34		2; 3.03; 3.03)	366
		2; 0,00; 0,00	
Numbers decisity Property State property line			
The fact and of the astrong			
at advanted in			
at unbranded under at annuality			
ELAN Data RUFU LXX Mocap/RUFU LX	OX ELAND-methods . Evolute Bots Bids	Let ELAN Results RURUXX +	
	CO. ELPERAPHONE PUBLIC POLIS DIVI	The second represent the second	



2.2.C Pipeline to determine how to find the kinematics in data using Unity3D and Excel

figure: Gesture comparison and development of a group signature

In order to compare the gestures between them, we chose to study the normalized distributions of the vector's magnitudes of velocity, acceleration and jerk on the basis of the normalized gesture execution time with 50 samples. By combining all these values, we can compute an average distribution that allows us to characterize the "gesture dynamic" according to unbounded and bounded video coding and the populations studied here (FRFR, RURU, RUFR).

To do this, we have developed in addition to the pipeline our own information extraction and visualization tools that compute the velocity, acceleration and jerk vectors on the basis of the positions expressed in the Cartesian reference frame used for motion captures (figure below). The tool also standardizes and formats the data so that it can be analyzed in a second step with statistical tools.

2.3 Visualizing results and interpretation

Depending on each analysis, the results can be presented in plots with statistical analysis or curves. We also developed a visualization system in Unity3D 3D designed to visualize gesture descriptors such as kinematics in real-time. We detail the different results in the next paragraphs.

Ego-centered

(First person)

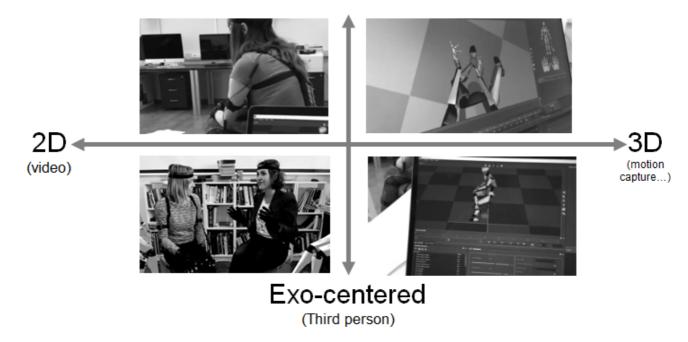


figure: ego or exo-centered points of view (Berthoz, 2000) regarding 2D video or 3D mocap data collections

2.3.A Visualizing aspectuality and statistics in Excel

After the gestures were coded in Elan, we are able to export the tire to a CSV file to analyze data in Excel. This part of the pipeline is not different from a classic gesture analysis except the analyze itself has been done with video and mocap video which allows a better understanding of gesture.

Indeed, using the mocap video we are able to "separate" the body envelop filmed by the camera from the Skeleton. Also, the mocap system we use doesn't capture the facial expressions of the participants. Some motion-capture system exists to capture facial movements, but in our study, we focus mostly on arms and hands movements. Facial expressions were not taken into account and then couldn't interfere in the process of gesture annotation in Elan.

Also, mocap allows to generate multiple points of view. For instance, an exocentered (third-person) point of view close to the one of the video camera. We can also use the advantage of the virtual cameras used in mocap to render for instance a mocap video fith a wider point of view or a close-up on specific body part of the participant. Finally, we can adopt an ego-centered (first-person) point of view of the participant to visualize and embody the gesture which is hard to achieve with a classic setup using a video camera.

2.3.B Kinesiology & Kinematics: Statistics and Curve Analysis in Excel

Regarding Kinesiology, we are able to estimate the range or motion of each degree of freedom (dof) for each segment (arm, forearm, hand). On thiinbasis, we extract the biggest amplitude at every frame. The dof thus marked is the one on which the second-largest amplitude determines finally the flow. The flow is calculated for every frame and the sum up is done for 1/ the whole gesture, 2/ the first half and 3/ the last half gesture. We note there are no significant differences between these three moments of each gesture. We decided then to focus on the whole gesture.

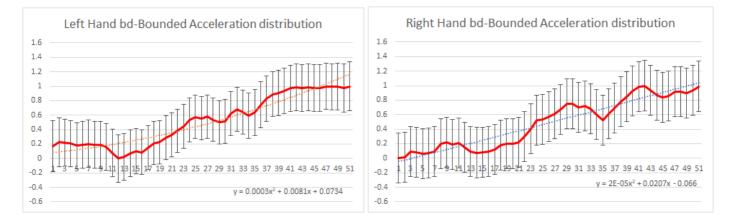
A second way we introduce to be more realistic is a weighting according to the motion of each segment. The assessment relies on an estimation of the range of motion. For instance, the complete amplitude of the flexion/extension of the hand is more than twice the one of the abduction/adduction of the same segment. The weighting is the double for the latter dof. The amplitude of the dof of the arm does not cover their full

ranges of motion. The mixing ratio overstates the motions for these dof. We have selected this mixing ratio. A third method to approach the flow introduces the standard variation for each dof. The dof follows a bell curve. We expect that every time a value is outside the standard variation, it is meaningful. We overrated the dof every time and this is critical to estimate the flow. All of our analysis have followed this last two ways to calculate.

Analyses are conducted on 15 pairs of participants. The analysis of the Motion capture is made on the basis of the video coding data under the Elan software by 3 different coders. We focus on the gesture analysis of gestures with the best triple consensus tagging which represents 348 gestures noted bounded and 148 gestures noted un-bounded for all the user panel.

In the context of bounded gestures coded with Elan, we obtain the following curves for both Hands. Each curve is expressed with the standard deviation on each sample and à polynomial trend curve of degree 2.

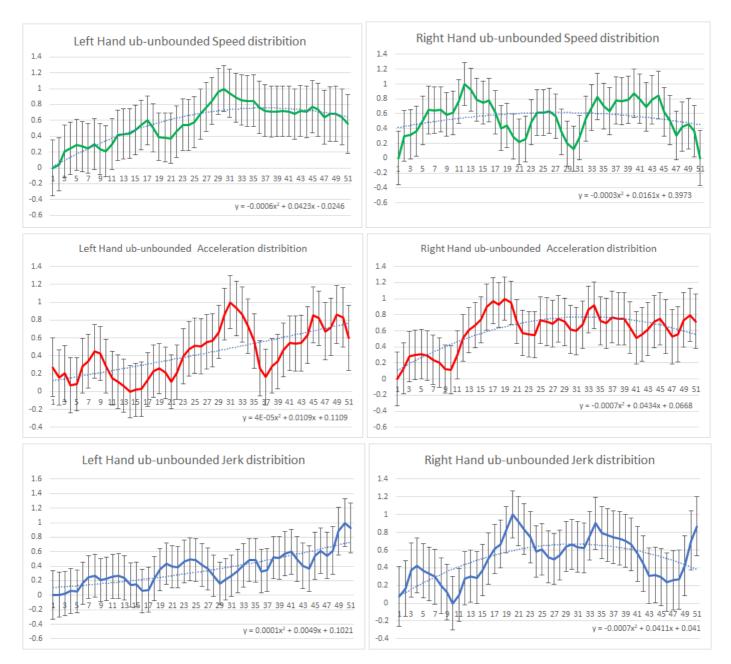






The motion capture analysis shows that both hands have the same behaviors, the bounded gestures have an increasing velocity, acceleration and jerk distribution profiles due to the nature of their shape. Given the number of samples, the standard deviation remains more or less constant on each sample.

In the context of un-bounded gestures coded with Elan, we obtained the following curves for both hands. Each curve is expressed with the standard deviation on each sample and polynomial trend curve of degree 2.



The motion capture analysis shows that the un-bounded gestures have velocity, acceleration and jerk distribution profiles less pronounced than the bounded gesture ones due to less affirmed gesture dynamic. Given the number of samples, the standard deviation remains more or less constant on each sample.

Overall, there is a significant visual difference between the curves that makes possible to distinguish bounded and unbounded gesture on the basis of this gesture analysis approach.

The main outlook of an approach to automatically distinguish each bounded and unbounded gesture from the mocap data could be the use of a learning machine algorithm based on these curves and the gesture video coding as a ground truth.

2.3.C Augmented Reality Player in Unity3D for gesture descriptors

We developed in the pipeline a new visualization system for gesture descriptors in order to explore gesture kinematics in real-time. This tool helps in perceiving and understanding participants gesture. But it is also questioning how such a pipeline involving Mocap is changing in annotation. We show in the previous part how mocap allows no more a single point a view but as many as required since we can use virtual camera to visualize the skeleton of the participant. We can now adopt first person point of view to better understand

participants gesture. With the tool developed in the Unity3D software, we are now able to visualize in real-time multidimensional gesture features (such as velocity, acceleration or jerk) or a combination of them in simpler curve or surface representations. We can then study gesture in an immersive and embodied point of view of the participant and visualizing its gesture in a real-time simulation using augmented reality.

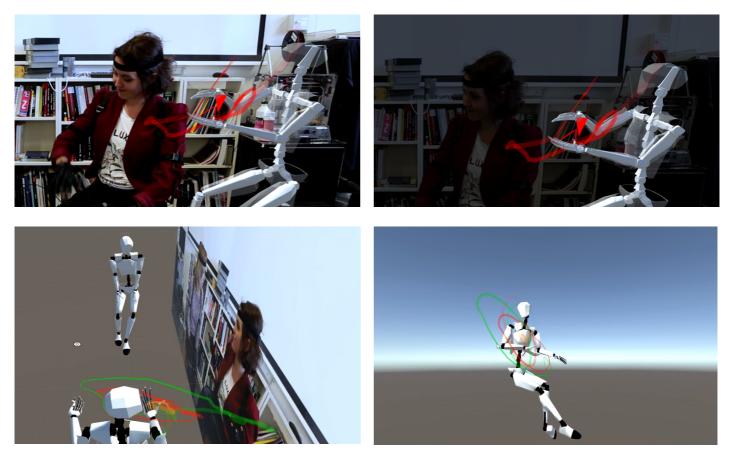


figure: Top: augmented reality visual rendering of gesture kinematics, focus can set on the video or the avatar. Bottom: capture of different points of view in the real-time viewport. Legend of the trails of the right hand of the participant in the right: the position is in orange, the velocity is in green and the acceleration is in red.

Acknowledgment

We wish to thank all the participants of the pre-tests and the study. The research was carried out at Moscow State Linguistic University and supported by the Russian Science Foundation (project No. 14-48-00067П).

References

Alemi, O. & Pasquier, P. & Shaw, C. (2014). Mova: Interactive Movement Analytics Platform. ACM International Conference Proceeding Series.

Berthoz, A. (2000). The brain's sense of movement (Vol. 10). Harvard University Press.

DCNC Digital Cinema Naming Convention V.9.5 (2018). Retrieved from http://isdcf.com/dcnc/

Okun, J. A., & Zwerman, S. (Eds.). (2010). The VES handbook of visual effects: industry standard VFX practices and procedures. Taylor & Francis.